Observation report on Ckoirama and image processing of the galaxy M83

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During the night of June 19, 2025, observations of the spiral galaxy M83 were made using the Chacana telescope (CDK24, 0.6m, f/6.5) installed at the Ckoirama observatory, operated by the University of Antofagasta. Images were acquired in 1×1 binning with the FLI ProLine 16801 CCD camera, using Sloan g, r and i filters. A total of 120 scientific exposures (40 per filter) were obtained with individual times of 120 seconds, complemented by calibration shots: 30 bias, 20 darks (120s) and twilight flat-fields per filter (44s). Observing conditions were stable, with mostly clear skies and relative humidity of 27%. The main objective was to obtain images of the galaxy M83 for analysis and construction of a composite RGB image. The reduction was performed following standard CCD preprocessing procedures: bias and dark subtraction, flat-field correction, and sigma-clipping stacking. The filter-combined images are presented as a preliminary analysis result.

I. INTRODUCTION

The galaxy M83, also known as the Southern Pinwheel Galaxy, is one of the nearest and brightest spiral galaxies in the southern sky, located at a distance of approximately 15 million light-years [1]. Its well-defined morphology and intense star formation activity make it an ideal target for studies of galactic structure, star formation, and the evolution of stellar populations. This observation is part of the Master's degree course in Observational Astronomy as an exercise in multiband CCD image acquisition and reduction. The objective of this exercise is to put into practice practical knowledge of telescope operation and the acquisition of quality scientific data for astronomical image composition analysis.

The observations were carried out on June 19, 2025, starting at 22:00 UTC from the Ckoirama Observatory, operated by the University of Antofagasta. Using the Chacana telescope, a 0.6m aperture, f/6.5 CDK24 reflector mounted on a Mathis MI-1250 equatorial mount and equipped with a FLI ProLine 16801 CCD camera, with Sloan G, R, and I photometric filters, the campaign was developed by a group of master's students, a student guide, and experienced researchers.

The program included the acquisition of calibration images (bias, dark, and flats), as well as 120 scientific exposures in 1x1 binning, distributed equally among the three filters used. Despite some technical issues with the weather station and focus adjustments during the night due to abrupt temperature changes, sky conditions were mostly stable, with a relative humidity of 27% and no significant wind or moon.

This report first presents the observational methodology used, followed by CCD image reduction, which includes preprocessing with calibration images and data blending. Finally, the results obtained are presented, including the filter-stacked images, and a preliminary discussion of their quality and usefulness for analysis.

II. METHODOLOGY AND RESULTS

A. Observation

This section will describe the observations carried out on June 19th of this year. The session began at 21:00 UTC with instrument calibration. First, the camera's operation was checked and the cooling process began. Then, the dome was opened and the weather station failure was recorded. Subsequently, the calibration images were acquired, following this order:

- Bias: 30 images with an exposure time of 0 s, in 1×1 binning, captured at 21:05 UTC.
- Flat-fields: 11 images were acquired for each filter:
  - g (4 s) and i (5 s) at 22:33 UTC.
  - r (4 s) at 22:35 UTC.

The flat-fields were taken during evening twilight, in 1×1 binning. As already mentioned, technical

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issues with the meteorological station occurred during the night, preventing automatic seeing and wind measurements. Despite this, observations were able to continue thanks to the generally stable sky. The relative humidity was 27% and was recorded at 03:58 UTC.

For focusing, the globular cluster M68 was used as a reference. The initial focus was made at 23:13 UTC, with a series of 13 3-s images in 1x1 binning, with a star size (estimated FWHM) of 1.94 px.

Scientific observations officially began at 00:01 UTC. The observed object was the galaxy M83. The following were obtained:

- 40 images in the g filter
- 40 images in the r filter
- 40 images in the i filter

All scientific exposures were made in 1x1 binning and with an integration time of 120 s per image. At 00:30, during image number 34, interference by a satellite was observed. Observation continued normally after this event. Additional focus adjustments were made overnight, particularly for the r filter (at 02:42 UTC) and for the i filter at various times (03:45, 04:00, 04:18, 04:24 UTC), all using series of 11 3-s images. The observation ended at 05:37 UTC after the dome closure.

B. Image processing

The obtained astronomical images underwent a scientific reduction and reconstruction process using Python, SAOImage DS9, and GIMP, following the principles of standard CCD image processing. The astropy, ccdproc, numpy, and matplotlib libraries were used, and the procedure was executed in a controlled Jupyter Notebook environment, optimized to reduce RAM usage through functions. The reconstruction process consisted of three main stages:

1. Construction of Master Calibration Frames

- Master Bias: created from 30 0-second bias images using median pooling from the numpay library (np.median), removing the fixed electronic pattern introduced by the reading [2].
- Master Dark: Obtained from 20 dark images of 120 s each (same exposure as the scientific images), previously corrected, along with the master bias, with the median (np.median). This frame eliminates the dark current and associated noise [2].
- Master Flat: Created with a (g, r, i) filter by subtracting planar images with bias correction and normalization. Correcting pixel-by-pixel sensitivity and variations in the optical system [2].

$$\mathrm{MasterFlat} = \frac{\mathrm{median}(\mathrm{Flat} - \mathrm{MasterBias})}{\mathrm{mean}\left(\mathrm{median}(\mathrm{Flat} - \mathrm{MasterBias})\right)} \tag{1}$$

In this equation the flat is normalized and ready to be implemented in the construction of the image.

2. Individual Calibration of Scientific Images

Each of the 120 images of the galaxy M83 was calibrated using the following workflow:

Individual Calibration of Scientific Images Each of the 120 images of the galaxy M83 was calibrated using the following workflow:

$$I_{\mathrm{cal}}(x,y) = \frac{I_{\mathrm{raw}}(x,y) - \mathrm{MasterDark}(x,y)}{\mathrm{Normalized\ MasterFlat}(x,y)} \tag{2}$$

This is the raw image, pre-bias corrected [2]. This procedure isolates the true astronomical signal, systematically eliminating the instrumental and thermal components. To reduce memory usage, each calibrated image was temporarily saved to disk and immediately released from memory.

3. Filter Stacking

Once the calibration steps described in the previous section II B were completed, the scientific images were aligned independently for each filter (g, r, i). This intra-filter alignment aims to correct shifts due to guiding or small mechanical variations between exposures.

To achieve this, a phase correlation-based technique was implemented using the phase_cross_correlation function of the skimage.registration package, with an oversampling factor of 20 to improve subpixel registration accuracy, since other methods such as Astroalign failed to detect reference objects adequately to align all the images. Each set of reduced images was aligned with respect to an automatically selected reference image (the first in the set), and the estimated shift was applied through interpolation with scipy.ndimage.shift.

The result of this step was a set of filter-aligned images, which were then combined by median to generate a final image stacked for each spectral band. Subsequently, the stacked images from each filter were aligned to construct a composite RGB color image. In this step, the Fourier-domain chi-square correlation alignment method was used, implemented with the chi2_shift function from the image_registration module.

The combined image from filter r was taken as a reference due to its good signal-to-noise ratio, and the stacked images from filters g and i were aligned with respect to it. The detected shifts were applied using shiftnd from the same package, ensuring precise alignment in pixel space. The final product of this step was a set of images perfectly aligned in all three bands.

C. RGB Image Composition DS9

To generate the color image of the galaxy M83, SAOImage DS9 software was first used. The images, previously calibrated II B and aligned with the g, r, and i filters, were combined into a single RGB image. In this composite, the color channels were assigned as follows:

- Red channel (R): image from the i filter
- Green channel (G): image from the r filter
- Blue channel (B): image from the g filter

This mapping does not follow the standard Sloan photometric color assignment, as after consulting with the telescope operators, it was reported that the filters were incorrectly positioned. In particular, the i filter, which captures longer wavelengths, was assigned to the red channel, while the g filter was assigned to the blue channel, and the r filter was assigned to the green channel. The following steps were implemented in the software:

1. In the top menu, select "Frame" - "New RGB Frame."
2. In the "Color" menu, we went to "RGB" and selected.
3. The levels of each channel were adjusted individually to improve contrast and highlight the bright and dim regions of the galaxy.
4. The composite image was exported in PNG format.

FIG. 1. Viewing the galaxy M83 on DS9.

D. Creating Images with GIMP

Here I describe the step-by-step process for combining data, just like in the previous section, into a color image using GIMP.

1. Open FITS Files: Launch GIMP and open the FITS files corresponding to each color channel (red, green, blue) as individual layers within the

same project. GIMP has native support for this format. Change Image Mode to RGB: This was done in the Images menu, Mode equals RGB.

2. Apply "Screen" Blending Mode: For each of the color layers (red, green, blue), apply the "Screen" blending mode. This allows the highlights of each layer to combine additively, creating a brighter and more detailed image.

3. Colorize Layers Individually: Each layer was assigned the corresponding color (red, green, blue) using GIMP's colorization tools, just as in DS9 II C. This involves adjusting the hue, saturation, and lightness so that each layer automatically represents its original color.

4. Adjust Levels per Channel: Use the Levels tool for each color channel (red, green, blue) individually. It's recommended to start with the "Automatic" option and then make fine manual adjustments to optimize brightness and contrast. This step is crucial for enhancing the image's details and aesthetics.

5. Export as PNG: Once the result is complete, export the final three-color image in a suitable file format, such as PNG, to preserve quality and detail.

FIG. 2. Viewing the galaxy M83 on GIMP.

III. CONCLUSION

The observation of the galaxy M83, carried out on June 19, 2025, from the Ckoirama Observatory using the Chacana telescope, successfully completed image acquisition, calibration, and processing. By capturing images with Sloan filters (g, r, and i) and systematically using calibration frames (bias, darks, and flats), the signal was efficiently isolated from instrumental and atmospheric noise.

Processing in Python, based on the classic CCD reduction model and supported by DS9 and GIMP, enabled image reconstruction, significantly improving the signal-to-noise ratio and facilitating future exploitation of color composition. However, this practice presents only a basic methodology for image processing; with greater experience using artistic tools, the results may improve significantly. All steps can be found in the repository in GitHub corresponding to this project.

[1] Andrea Gianopoulos, Dana Bolles, and NASA (2025). Hubble Messier Catalog: Messier 83. `https://science.nasa.gov/mission/hubble/science/explore-the-night-sky/hubble-messier-catalog/messier-83/`. Page Last Updated: Apr 25, 2025.

[2] Berdja, A. (2025). CCD Image Processing - Introduction. Page Last Updated: jun 18, 2025.